12. LATE QUATERNARY SEDIMENTS OF THE SOUTHERN MEXICO MARGIN[1]

Kenneth J. McMillen, Gulf Science and Technology Company, Pittsburgh, Pennsylvania
and
Trent R. Haines, Amoco Production Company, New Orleans, Louisiana

ABSTRACT

Late Quaternary sediments of the southern Mexico margin, sampled by piston coring, consist predominantly of micaceous sandy mud. Significant sand accumulations occur as thick, clean sands on the shelf and in the trench; lesser amounts occur as thinner, fine-grained turbidites or contourites on the lower slope and trench. Midslope and upper slope sediments are nearly all muddy. Sedimentation rates are lower on the middle slope than on both the upper and lower slope and, together with the fine-grained nature of slope sediments, indicate that sand bypassed the slope through submarine canyons.

Coarse, clean, thick-bedded terrigenous sands were cored only in the trench and were not found anywhere on the slope. These trench sands differ from shelf sands in that the latter have significant biogenic skeletal components. Trench sands must be derived directly from the littoral drift system, whereas shelf sands are not reworked over the shelf edge and downslope to contribute to the lower slope and trench depositional system.

INTRODUCTION

With the advent of plate tectonic theory, marine geologists have devoted greater attention to deep sea trenches. Models for the formation of accretionary zones landward of the trenches from deformed trench and oceanic sediments (Seely, et al., 1974; Karig and Sharmon, 1975; Moore and Karig, 1976) show the importance of these deposits in active margin geology. Concurrent with the development of these tectonic-accretion models has been an emphasis on a better understanding of trench and lower slope depositional processes (Piper et al., 1973; von Huene, 1974; Kelling and Stanley, 1978; Schweller and Kulm, 1978). Only recently has the role of submarine canyons in trench sedimentation processes been emphasized, and trench sediments related to other contemporaneous sediments of the active margin and to active margin morphology (McMillen et al., 1977; Underwood and Karig, 1979).

The purpose of this descriptive account of late Quaternary sediment distribution on the southern Mexico margin is twofold: (1) to provide a modern analog for interpretation of the depositional environments of Leg 66 sediments, and (2) to provide data for an interpretation of depositional processes across this active margin.

Previous investigations of the southern Mexico margin have defined the regional geologic setting (Shipley et al., 1980; de Cserna, 1965). The southern Mexico active margin differs from most in that the zone between the trench and volcanic chain contains older Pre-Cambrian through Mesozoic sedimentary, metamorphic, and crystalline igneous rocks whose structures trend offshore and appear truncated. This large crystalline source provides quartz- and feldspar-rich sands distinctly different from the volcaniclastic sands offshore Central America (Enkeboll, in press).

The offshore morphology, described by Shipley et al. (1980, fig. 1), is more irregular than the margin offshore Guatemala (Ladd et al., 1978). Trench sediment fill is restricted to small isolated basins with no apparent interconnection by axial channels. Small channels within the trench may be flanked by ridges representing either levees or incipient deformation of trench sediment. Several large submarine canyons cut transverse to the slope, but only one extends to the trench. This canyon, largest of the study area and located at roughly 99°W, is here named Ometepec Canyon after a river system by that same name that empties into the Pacific near the canyon head. The remainder of the slope has two major morphologic features: (1) shelf edge and upper slope indentations (Fig. 1) apparently related to continental basement structures and (2) lower slope terraces produced by tectonic compression or sediment slumping. The lower slope terraces apparently block all other submarine canyons within the study area except Ometepec Canyon. Two large levee-like structures parallel the lower course of Ometepec Canyon below the 2600-meter contour to the trench (Fig. 1).

Sediments of the southern Mexico margin were sampled in 21 piston cores on two cruises of the University of Texas *Ida Green:* I.G. 24-5 in summer 1977 and I.G. 29-3 in summer 1978. For convenience, only core numbers will be used in this report; cores from I.G. 24-5 are numbered 25 through 37; cores from I.G. 29-3 are numbered 1 through 9. Satellite navigation was used for positioning for coring and bathymetry. Water depths were corrected with Matthews Tables. Cores were collected with a 6.3-cm (2.5 inches) diameter Ewing piston corer fitted with plastic liners and were split onshore several months after collection. Although the cores were stored unrefrigerated aboard ship, drying, bacterial growth, and color changes appeared minor. Core de-

[1] *Initial Reports of the Deep Sea Drilling Project*, Volume 66.

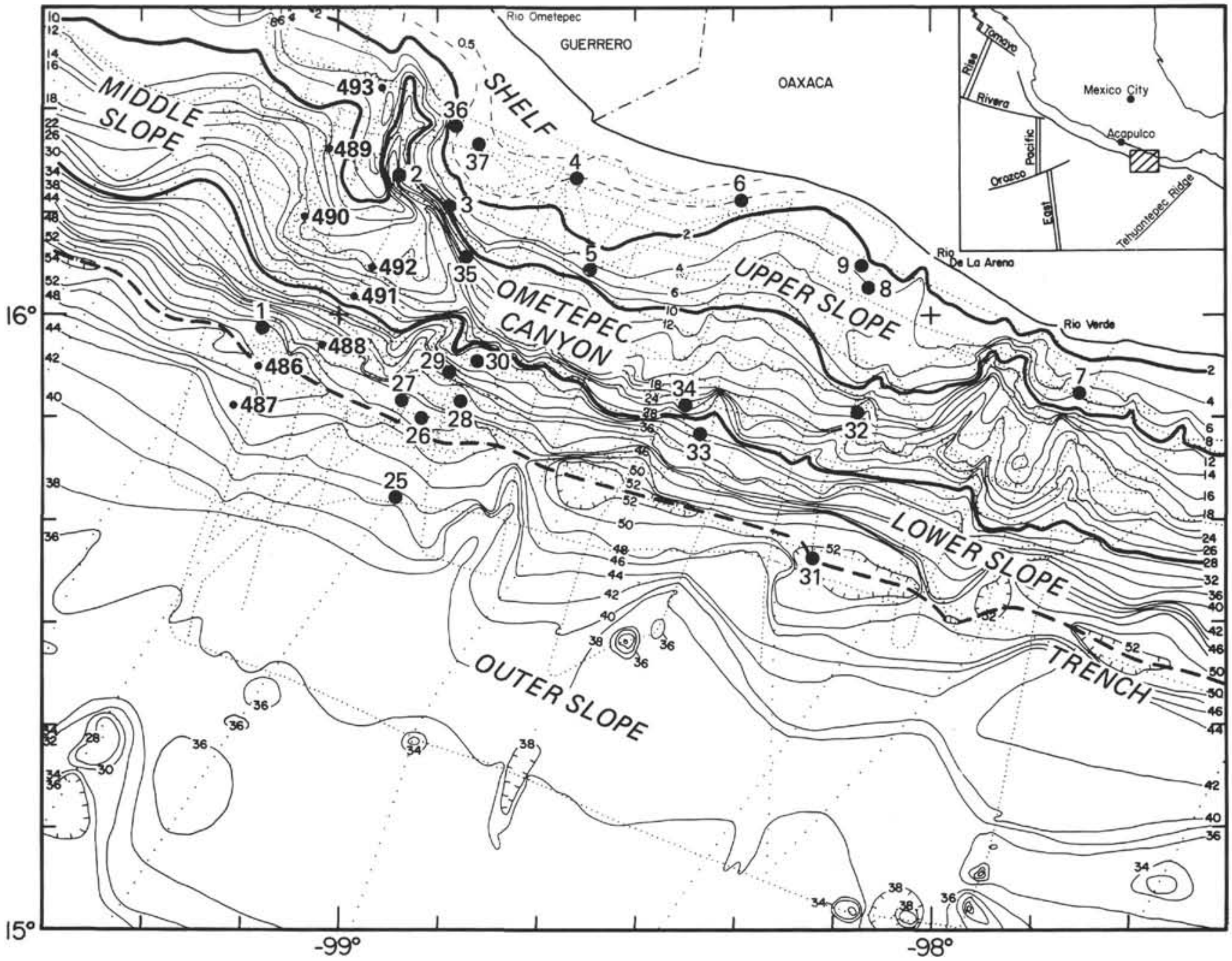

Figure 1. Bathymetry of the southern Mexico margin offshore from the states of Guerrero and Oaxaca, in corrected meters. Track lines for bathymetry shown as dotted lines. Piston core locations (large dots) and Leg 66 sites (small dots) also shown. Environmental boundaries, for this report only, are arbitrarily set as: shelf, 0–200 m; upper slope, 200–1000 m; middle slope, 1000–3000 m; lower slope and trench, greater than 3000 m. Trench axis is dashed.

scriptions followed a format of color, lithology, and structural observations and semiquantitative coarse fraction analysis from every 1 meter of core in addition to smaller lithologic units (results from some sands are reported in Table 1). Paleontological determinations, described later under Dating and Sedimentation Rates, were made on conventional strewn slides of washed sediment residues retained on a 63 μm mesh screen. Enkelboll (this volume) reports on petrologic and textural studies on these cores.

SEDIMENT DISTRIBUTION

Despite a variety of environments from which the 21 piston cores were collected during the site surveys (Fig. 1), most cores recovered monotonous sequences of micaceous sandy mud. Significant sand accumulations were found only on the shelf and in the trench. The following summary of the major environments from trench to shelf emphasizes macroscopic core descriptions and the semiquantitative coarse fraction analyses.

Trench

Sediment type varies along the trench axis in the depositional ponds (Fig. 2). Most trench cores came from the sediment pond at the base of Ometepec Canyon, also cored by Leg 66 at Site 486. Core 27 from the mouth of the canyon contains massive, coarse, clean sand with rock fragments derived upslope or onshore from the crystalline terrane. Core 26, taken close to 27, contains finer-grained, clean sand with a few muddy layers (Fig. 2). Core 1, recovered from the inner slope next to the sediment pond with Cores 26 and 27, contains muddy turbidites with a Bouma C-E sequence and abundant plant debris. A different trench pond, sampled in Core 31, also contains muddy turbidites with Bouma C-E intervals and laminated zones of mud and sand. All

Table 1. Sand composition data from shelf, trench, and lower trench slope from the southern Mexico margin recovered in piston cores. Note the similarity of trench and lower slope sands and the marked contrast between those sands and shelf sands that contain much more calcareous skeletal debris. See Bachman and Leggett (this volume) and Enkeboll (this volume) for additional data on sand composition.

	Shelf Sands							Trench Sands																Lower Slope Sands			
Cruise	I.G. 24			I.G. 24				I.G. 24					I.G. 24						I.G. 24			I.G. 29	I.G. 24		I.G. 24	
Core No.	36			37				31					26						27			1	25		28	
Depth (cm)	0	100	198	0	15	100	194	160	200	241	300	440	0	90	100	155	200	202	0	100	200	110	394	550	327	428
P. foraminifers	C	R	R			R	R		R														R	R	R	
B. foraminifers	C	C	C	R	R	R	R	R	R	R			R		R		R	R				R	R	R	R	R
Radiolarians				R						R		R						R								
Diatoms				R																			R			
Pteropods	R	R	R	R	R	R	R																			
Sponge spicules	R	R	R	R		R	R																			
Ostracodes			R	R		R	R									R	R	R				R			R	
Molluscs	C	C	C	A	A	C	C										R									
Coralline algae	A	A	A	C																						
Coral	R	R	R	R	R	R	R																			
Bryozoa	R	R	R	R	R	R	R																		R	
Quartz	R	R	R	R	R	C	C	A	C	C	C	A	A	A	A	A	A	A	A	A	A	C	C	C	A	A
Feldspar									R	R	R	R	C	R	R	R	R	R	R	R	R	R	R	R	R	R
Manganese	R	R	R	R	R	C	C	R	R	C	R	C	R	R	R	R	R	R	R	R	R	R	R	R	R	R
Opaque minerals	R	R	R	R	R	R	R	C	C	R	R	C	C	R	R	C	R	R	R	R	R	R	R	R	R	R
Rock fragments	R	R	C	C	C	C	C	R	C	C	R	C	C	R	R	R	R	R	C	C	C		R	R	R	R
Plant debris								R	R	C	A	R						R	R				A	R		
Ash								R					R	R	R		R							R	C	R
Mica		R	R					C	C	R	R	R	C	C	R	C	C	A	C	C	R	A	C	C	R	R

trench sands consist of quartz, feldspar, mica, and lithic rock fragments with little biogenic skeletal material (Table 1).

Lower Trench Slope (>3000 m)

Outer slope Core 25 and inner lower slope Cores 28 and 29, containing thin sand beds interbedded with mud and capped by roughly 3 meters of hemipelagic mud, are visually nearly identical (Fig. 2). Thin, evenly spaced sand beds in Core 25 have sharp upper and lower contacts and resemble contourites (Bouma and Hollister, 1973). Sand beds in lower inner slope Cores 28 and 29 are more widely spaced, not rhythmically bedded, and may be thin-bedded turbidites. Farther upslope the lower inner slope Cores 30 and 33 contain hemipelagic mud only (Fig. 2). Like the trench fill, sands from the lower slope consist of mostly quartz, feldspars, and mica but with fewer rock fragments because of a finer-grain size (Enkeboll, in press) and with rare biogenic constituents (Table 1).

Middle Trench Slope and Canyon (3000–1000 m)

Middle trench slope Cores 34 and 32 are uniformly composed of hemipelagic mud with no sedimentary structures other than thin color laminations in Core 34. Ometepec Canyon Cores 2 and 3 contain mud and gravel layers with metamorphic rock fragments. Shipley et al. (1980) report dredging biotite–hornblende gneiss and gabbro as well as volcanic rocks and mudstone from the location of Core 2, showing that these gravels are locally derived from the canyon walls.

Upper Trench Slope (1000–200 m)

Upper slope cores contain laminated mud or mud with sand laminae in Core 35 near Ometepec Canyon. Cores containing laminations vary in water depth from roughly 400 to roughly 1000 meters. Laminations in Cores 5, 7, 8, and 9 are recognized by contrasting colors, but in Core 35 they are thin, fine-grained, clean sands with ripple bedding and channelling (Fig. 3B).

Burrowing is virtually absent from all laminated zones in upper slope cores except in a hemipelagic mud cap 0.2 to 1.0 meter thick.

Shelf (<200 m)

Shelf Cores 36, 37, and 6 contain massive, clean sands with molluscan shells, coral, and calcareous algae (Table 1). Outer shelf Core 6 is capped with 1.8 meters of hemipelagic mud and outer shelf Core 4 is all mud except for a thin sand bed at 3.5 meters. Shelf sands differ from trench and lower slope sands in containing more calcareous biogenic components such as shells, benthic foraminifers, coral, algae, and containing less quartz, feldspar, mica, and rock fragments.

DATING AND SEDIMENTATION RATES

Some of the piston cores collected during cruise I.G. 24 were dated micropaleontologically. All cores except Core 32, which may bottom in late Miocene mudstone, are younger than the *Axoprunum angelinum* extinction level of 0.4 m.y. (Hays, 1970) and are therefore late Quaternary. Dating such young sediments is hampered owing to intense carbonate dissolution on the middle and lower slope (McMillen and Bachman, this volume), so that planktonic foraminifers cannot be used. Elements of the radiolarian fauna commonly used in low latitude biostratigraphy (Nigrini, 1971) are also absent in this nearshore, upwelling area (McMillen, this volume). A technique of estimating the age of late Quaternary sediments offshore Guatemala, based on the ratio of nassellarian (cone-shaped) radiolarians to spumellarian (spherical) radiolarians (McMillen, 1979), was used

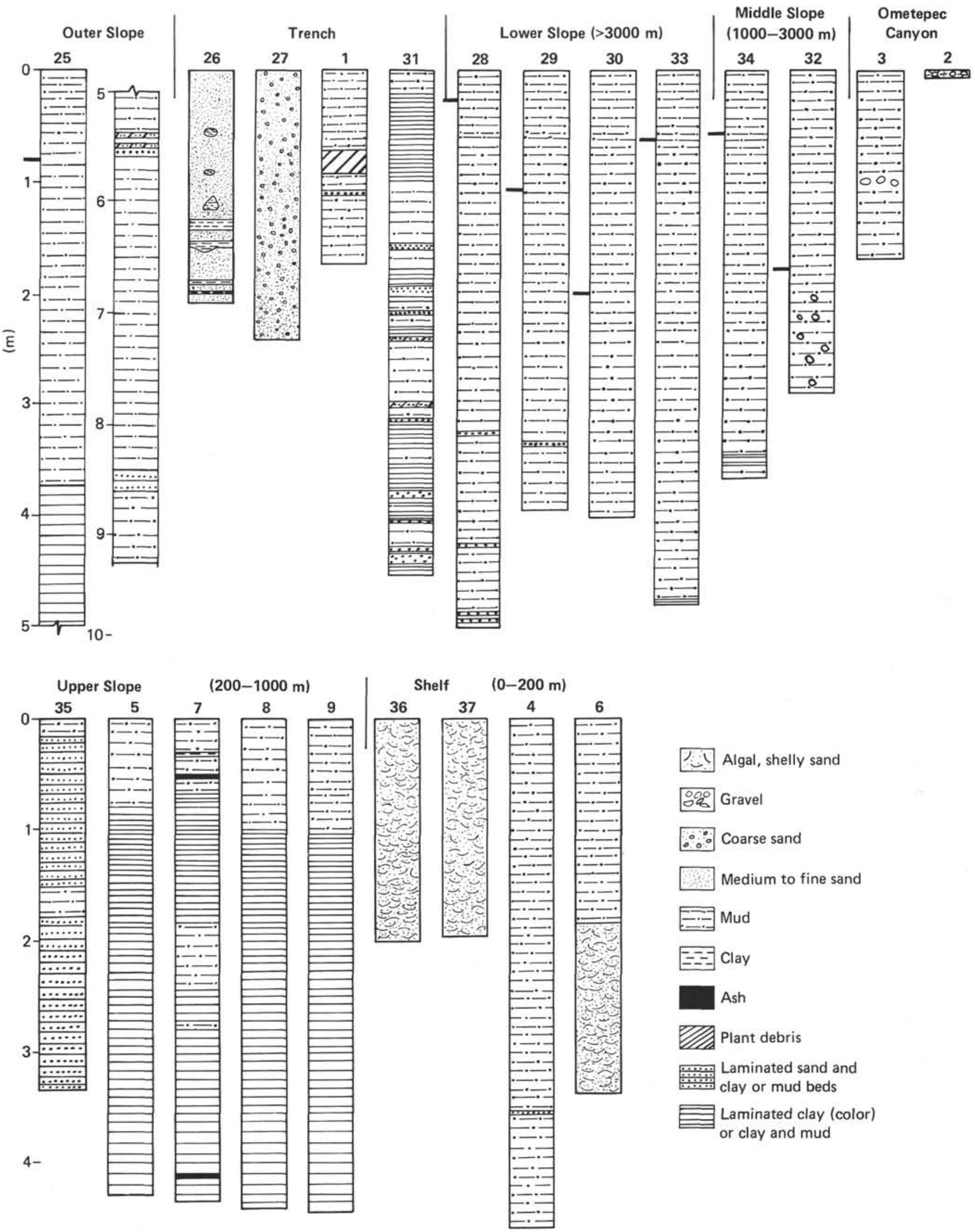

Figure 2. Summary of core lithologies. Note especially the massive sands on the shelf and in the trench and the predominance of micaceous sandy mud on the slopes. Sediment symbols used in this digram may vary from the traditional ones used in IPOD lithologic columns.

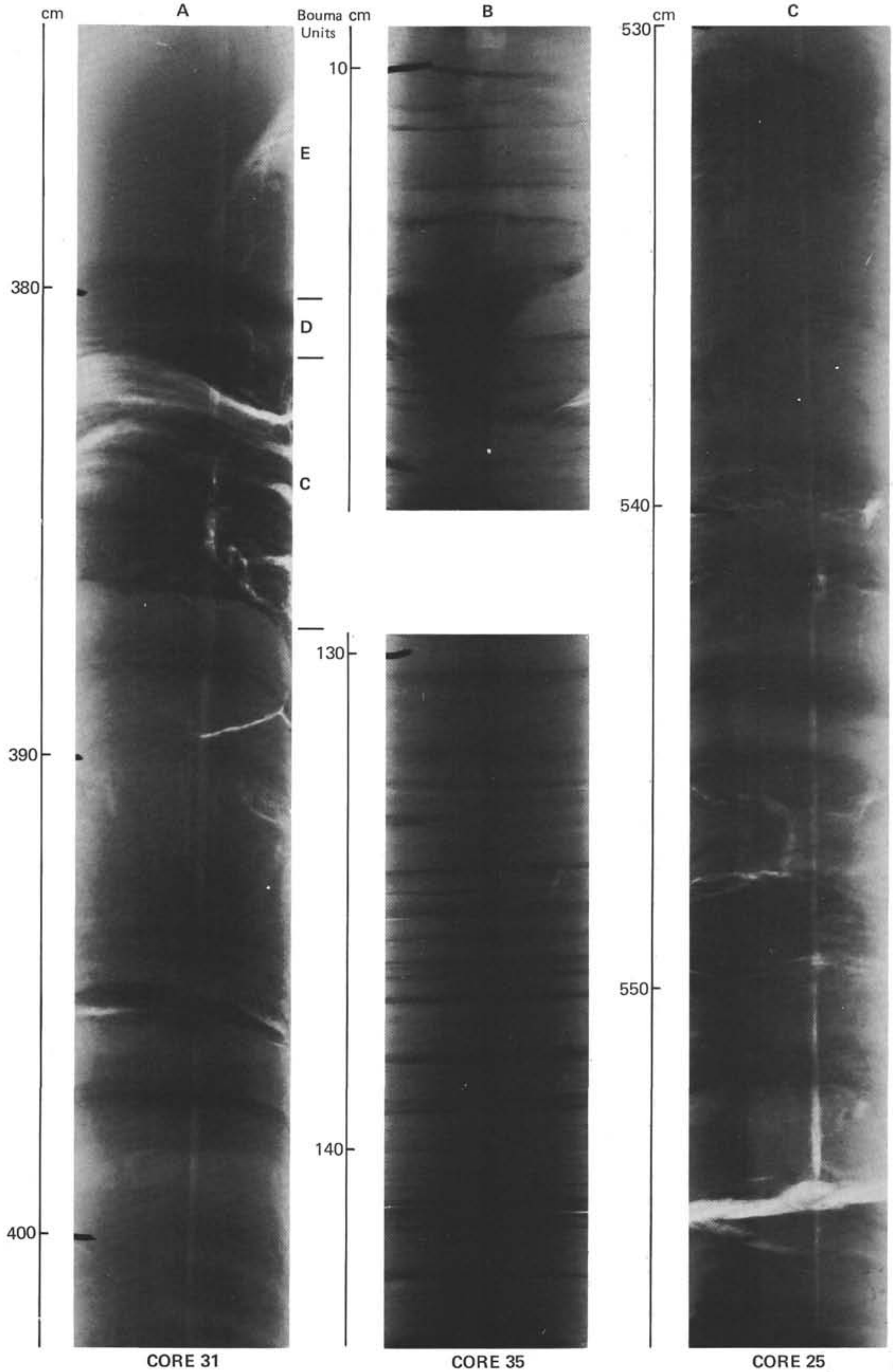

Figure 3. Radiographs of sand beds on the southern Mexico margin. A. Turbidites in Core 31 from the trench showing C, D, and E Bouma units. B. Upper slope sand laminae and channel in Core 35 possibly deposited by contour currents. C. Possible contourite sand beds from outer slope Core 25.

offshore southern Mexico. This ratio, which reaches a minimum value in the late Pleistocene, presumably responds partly to shoreline proximity and is therefore an indirect sea level indicator. Offshore Guatemala, this minimum point can be roughly correlated with a late Pleistocene–early Holocene elevation of the CCD which is expressed as a loss of calcareous microfossils in late Pleistocene or Holocene sediments. This carbonate "line" has been shown to be time-transgressive offshore Oregon (Barnard and McManus, 1973). Nevertheless, the radiolarian ratio minimum seems to be a good time-synchronous indicator of the late Pleistocene lowering of sea level. This minimum point has been plotted on the I.G. 24 cores and used for correlations (Fig. 4).

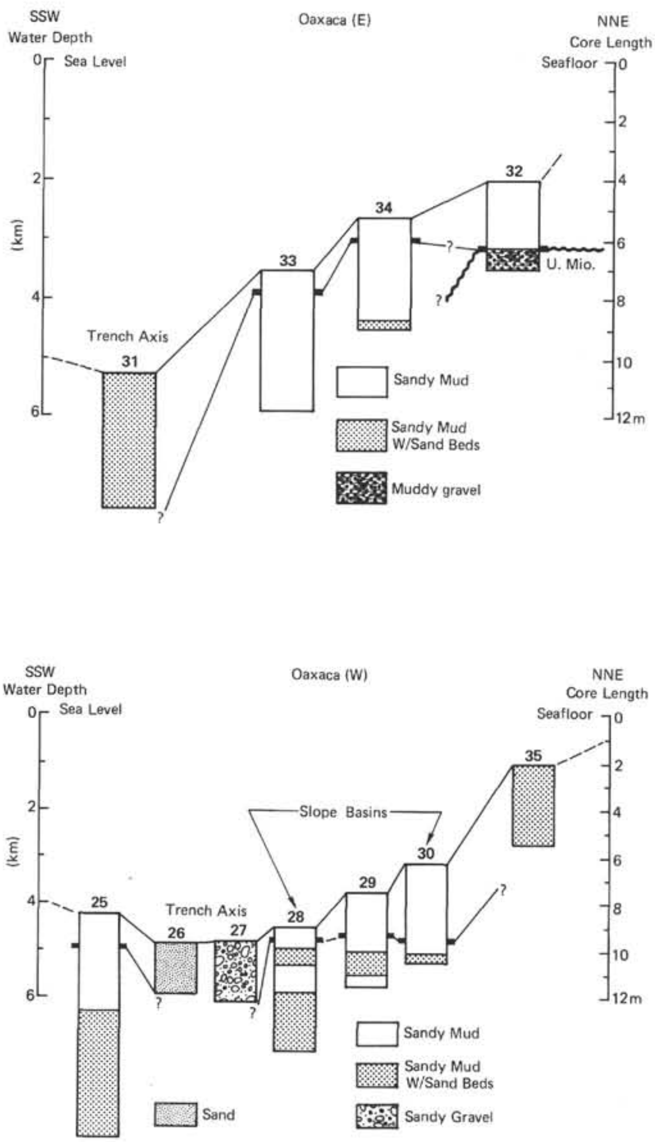

Figure 4. Correlation diagrams across the middle and lower slope and trench offshore southern Mexico showing major facies types and the late Pleistocene Nassellarian/ Spumellarian radiolarian ratio minimum. Correlation of the ratio minimum, presumed to be time-synchronous, illustrates sediment bypassing of the lower slope. Thin lower-slope sand beds are all Pleistocene.

Two profiles across the lower slope and trench (Fig. 4) show variations in the rate of sedimentation above the radiolarian ratio minimum on the margin. Upper slope and trench rates are relatively high. The intervening middle slope is a zone of bypassing and somewhat slower sedimentation rates, consistent with the bypassing model for trench and slope sedimentation proposed by Underwood and Karig (1979).

DISCUSSION

A variety of depositional processes and facies occur on the southern Mexico continental margin. Trench sedimentation of massive, clean sands in Core 27 probably occurred by traction processes or grain flow. Deposition of fine-grained muddy sands was by turbidity currents, as deduced by Bouma sequences. Coarse, clean sands cored at Holes 486 and 486A to the northwest of Core 27 suggest that this sandy facies is widespread and may be typical for this trench fill. The turbidites of Core 1 are somewhat upslope from the trench axis toward the inner wall and may be overbank deposits or another trench facies derived from another, muddier source. Trench and lower slope terrigenous sands are distinctly different in composition from shelf sands (Table 1), which contain abundant biogenic skeletal constituents. Shelf sands apparently do not reach the slope and trench in significant quantities. The dominance of quartz, feldspars, mica, and plant debris in trench and outer and inner lower slope sands near Ometepec Canyon suggests a common fluvial or littoral drift source with little influence from the shelf. Petrologic differences between sands from trench and lower trench slope environments are directly correlative with grain size only and are not due to source differences (Enkeboll, in press). Clearly a river–submarine canyon system exerts a strong influence on trench sedimentation here.

The thin-bedded turbidites or contourites and hemipelagic muds of the inner and outer trench wall are virtually identical, precluding the differentiation of these two environments. The turbidites and contourites from inner and outer slope Cores 25, 28, and 29 are Pleistocene and were either uplifted to their present position after deposition in the trench, or, more likely, were deposited only during lowered sea level by turbidity and contour currents at essentially their present depth. The late Pleistocene sea level rise may have cut off or reduced coarse clastic sediment sources to these environments.

Upper slope laminated muds and mud with sandy laminae represent a distinct facies. Preservation of this facies is due to a lack of burrowing caused by lowered O_2 concentration, either from the breakdown of organic matter within the sediment or from deposition in the oxygen minimum zone. The sandy ripple laminations in Core 35 indicate moderate currents as depositional agents, probably slope currents or overbank flow from Ometepec Canyon. The fact that all of the 3.4 meters of Core 35 is Holocene indicates a higher sedimentation rate for this zone than for the middle slope.

Outer shelf and upper slope cores are capped by a zone of bioturbated hemipelagic mud, which suggests a decrease in the amount of sediment supplied to this zone, thus permitting benthic organisms to survive without threat of rapid burial.

Shelf sediments consist of biogenic skeletal and terrigenous sands distinctly different from similar textured sediments of the trench and lower slope. The lack of similar sands from sediments of even Pleistocene age downslope indicates that these shelf sands are not washed over the shelf edge even during times of lowered sea level. If slumping does generate turbidity currents on this margin, such slumps must not involve the shelly shelf sands to any appreciable extent.

CONCLUSIONS

Several distinct sedimentary facies are recognizable offshore southern Mexico: (1) clean, massive terrigenous trench sands derived from fluvial and/or littoral drift systems; (2) trench turbidites with Bouma C-E units; (3) lower slope hemipelagic mud and thin turbidite or contourite beds; (4) middle slope hemipelagic micaceous sandy mud; (5) upper slope laminated mud with laminated or rippled sand beds; (6) outer shelf hemipelagic mud; and (7) shelf algal, shelly, and terrigenous sand. In addition, rock fragments derived from canyon walls or onshore occur within Ometepec Canyon. Sediment bypassing of the Holocene shelf and slope through submarine canyons results in the slow accumulation of fine-grained hemipelagic sediments on the slopes. Sand accumulation is restricted mainly to the shelf and trench. We recovered coarse-grained, massive, clean sands with few biogenic grains only in the trench, not in Ometepec Canyon (Cores 2, 3) or any other channel or in any of the small lower slope basins. This strengthens the interpretation that coarse, clean sands recovered near the base of Leg 66 Sites 488, 491, and 492 represent older uplifted and accreted trench deposits. However, if a slope basin had formed across the axis of Ometepec Canyon, it would probably contain these same coarse sands.

The terrigenous trench sands seaward of Ometepec Canyon must be derived directly from a fluvial–littoral drift system and not from the shelf. Shelf sands, which in many ways resemble the basal sands of Sites 489 and 493, most likely are relict and seldom reworked into the trench and downslope. The trench sandy facies may be of very local extent, as our limited lateral sampling within the trench indicates a muddier turbidite facies elsewhere (Cores 1 and 31). None of the finer-grained turbidites contained appreciable shelly debris (Cores 1 and 31 in Table 1), suggesting that selective winnowing of shells by turbidity currents within the trench does not occur.

Ometepec Canyon has probably persisted in its present position for quite some time. The canyon head is well incised into the crystalline rocks of the upper slope. Tectonic adjustments of the lower slope due to underthrusting would not affect its location as long as it continued to deliver sand to the trench by erosive turbidity currents. Therefore the sandy trench facies seaward of Ometepec Canyon, while certainly unusual and perhaps atypical of the entire trench, has probably been in existence for a long time.

ACKNOWLEDGMENTS

We wish to acknowledge the assistance of Captain Otis Murray and crew of the *Ida Green* and the scientific staff at sea from the University of Texas Marine Science Institute. The bathymetry was compiled by T. H. Shipley and L. A. Sanchez-Barreda. H. Kim prepared paleontological slides, and F. Sebak drafted some of the figures. Ideas expressed in this paper developed through discussion with R. T. Buffler, T. H. Shipley, and R. H. Enkeboll. The manuscript has been improved by review by R. von Huene and L. Kulm. This investigation was supported by National Science Foundation Grant OCE-76-2330 and NSF IPOD contracts CU-TEX 25907-2, -3.

REFERENCES

Barnard, W. D., and McManus, D. A., 1973. Planktonic foraminiferan–radiolarian stratigraphy and the Pleistocene–Holocene boundary in the northeast Pacific. *Geol. Soc. Am. Bull.*, 84:2097–2100.

Bouma, A. H., and Hollister, C. D., 1973. Deep ocean basin sedimentation. *Turbidites and Deep-Water Sedimentation: Society of Economic Paleontologists and Mineralogists*, Short Course Lecture Notes, pp. 81–99.

de Cserna, Z., 1965. Reconocimiento geologico en la Sierra Madre del Sur de Mexico, entre Chilpaningo, Acapulco, estado de Guerrero. *Bol. Inst. Geol. Univ. Nac. Auton. Mex.*, Vol. 62.

Enkeboll, R. H., in press. Sedimentary petrology and provenance of sands from the Middle America Trench and trench slope: Guatemala and southern Mexico. *Am. Assoc. Pet. Geol.*

Hays, J. D., 1970. Stratigraphy and evolutionary trends of radiolarians in North Pacific deep-sea sediments. *Mem. Geol. Soc. Am.*, 126:185–218.

Karig, D. E., and Sharmon, G. F. III, 1975. Subduction and accretion in trenches. *Geol. Soc. Am. Bull.*, 86:377–389.

Kelling, G., and Stanley, D. J., 1978. Sedimentation in submarine canyons, fans and trenches: Appraisal and augury. *In* Stanley, D. J., and Kelling, G. (Eds.), *Sedimentation in Submarine Canyons, Fans, and Trenches:* Stroudsburg, Pa. (Dowden, Hutchinson, and Ross), pp. 377–388.

Ladd, J. W., Ibrahim, A. K., McMillen, K. J., et al., 1978. Tectonics of the Middle America Trench offshore Guatemala. *Proceedings of the Int. Symp. on the February 4, 1976 Guatemala Earthquake and Reconstruction Process*, Vol. 2.

McMillen, K. J., 1979. Radiolarian ratios and the Pleistocene–Holocene boundary. *Gulf Coast Assoc. Geol.Soc.Trans.*, 29:298–301.

McMillen, K. J., Buffler, R. T., Moore, J. C., et al., 1978. Sedimentation in the Middle America Trench off Oaxaca, Mexico, and Guatemala. *Am. Geophys. Union Trans.*, 58(No. 12):1150.

Moore, G. F., and Karig, D. G., 1976. Development of sedimentary basins on the lower trench slope. *Geology*, 4:693–697.

Nigrini, C., 1971. Radiolarian zones in the Quaternary of the equatorial Pacific Ocean. *In* Funnell, B. M., and Riedel, W. R. (Eds.), *The Micropaleontology of Oceans:* Cambridge (Cambridge University Press), pp. 443–461.

Piper, J. W., von Huene, R., and Duncan, J. R., 1973. Late Quaternary sedimentation in the active eastern Aleutian Trench. *Geology*, 1(No. 1):19–22.

Schweller, W. J., and Kulm, L. D., 1978. Depositional patterns and channelized sedimentation in active eastern Pacific trenches. *In* Stanley, D. S., and Kelling, G. (Eds.), *Sedimentation in Submarine Canyons, Fans and Trenches:* Stroudsburg, Pa. (Dowden, Hutchinson, and Ross), pp. 311–324.

Seely, D. R., Vail, P. R., and Walton, G. G., 1974. Trench slope model. *In* Burk, C. A., and Drake, C. L. (Eds.), *The Geology of Continental Margins:* New York (Springer-Verlag), pp. 249–260.

Shipley, T. H., McMillen, K. J., Watkins, J. S., et al., 1980. Continental margin of Guerrero and Oaxaca, Mexico. *Mar. Geol.*, 35:65–82.

Underwood, M. B., and Karig, D. E., 1979. Submarine canyons as a key to sedimentation in subduction complexes. *Geol. Soc. Am. Abstracts with Programs*, 11(No. 7):531.

von Huene, R., 1974. Modern trench sediments. *In* Burk, C. A., and Drake, C. L. (Eds.), *The Geology of Continental Margins:* New York (Springer-Verlag), pp. 207–211.